Technical Memorandum

City of Maricopa Master Drainage Study and Plan
Vekol Wash Tributary Hydrology

HDR

CITY OF MARICOPA
PROUD HISTORY · PROSPEROUS FUTURE

July 2009 (Revised August 2009)
HDR Project No. 097203

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Memo

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CC:	Elise Moore, Pinal County Floodplain Administrator		
Date:	July 23, 2009 (Revised August 27, 2009)	Job No:	HDR 97203

RE: Vekol Wash Tributary Hydrology Technical Memorandum

Introduction

This memorandum summarizes the work performed under the Vekol Wash Tributary Hydrology Analysis task item of the City of Maricopa Master Drainage Study. The purpose of the study is to develop a new hydrologic analysis to determine the flow from Vekol Wash Tributary that impacts the City of Maricopa.

The Vekol Wash Tributary watershed is approximately 196 square miles and bounded by the Union Pacific Railroad (UPRR) Tracks to the north, the Vekol Wash watershed to the west, the Table Top Wilderness mountains to the south, and the Santa Rosa Wash watershed to the east. The Vekol Wash Tributary joins the Vekol Wash approximately 4 miles to the north of the boundary of this study. The entire study lies within the Pinal County.

Two previous sources of flow information exist for the Vekol Wash Tributary. The flows published by FEMA in the 2007 Flood Insurance Study (FIS) indicate that 13,700 cfs arrive at the UPRR tracks. However, a LOMR was filed in 2007 that indicates 1,628 cfs arrive at the same location.

The purpose of this hydrology study was to determine a flow amount for sizing of proposed improvements that will accept the flow from the Vekol Wash Tributary at the railroad tracks. It was determined that neither of the two previously published flows could be used on this task for the following reasons:

- The FIS flow of 13,700 cfs was taken from regression equations and does not account for the unique conditions of the watershed due to development, flow splits, and agricultural uses.
- The LOMR flow of 1,628 cfs was based on very specific conditions in the upstream watershed, including the presence of specific agricultural crops and grading conditions. It is unlikely that these conditions will exist at all times, even within a single growing season, due to crop rotations and other reasons discussed further in Section 1.8.

1.0 HYDROLOGIC MODELING PARAMETERS

1.1 Methodology

The Pinal County Drainage Manual, Volume 2: Design Methdology and Procedures, Chapter 2: Hydrology indicates that "*The U.S. Army Corps of Engineers rainfall runoff model should be used for modeling larger, more complex watersheds, or for drainage networks requiring routing procedures. The SCS Type II 24-hour storm distributions with antecedent moisture condition II are generally acceptable. The HEC-1 methodology presented within the ADOT Highway Drainage Design Manual – Hydrology (latest revision) is acceptable for use on projects reviewed by Pinal County*."

The Drainage Design Manual for Maricopa County (DDMMC, November 2003 Draft) meets the requirements of the ADOT manual and the requirements of the Pinal County manual. The DDMMC is slightly more detailed and stringent in its requirements. The Green and Ampt rainfall loss method was used, which is acceptable to both DDMMC and ADOT. The individual loss parameters have been investigated and refined by HDR through previous work on numerous projects throughout Arizona. In particular, the loss parameters for agricultural fields (as discussed below) were carefully researched and chosen as they are unique for loss calculations.

The DDMMC's Draft manual has not been finalized. The main reason is that it uses NOAA 14 precipitation estimates for the County instead of the older NOAA 2 estimates. Maricopa County is in the process of finalizing the DDMSW software that accompanies the manual prior to releasing the manual out of draft form. Please note that HDR used NOAA 14 precipitation estimates on this project, which is the same precipitation used on the LOMR model. The NOAA 14 estimates have been accepted by ADOT.

Therefore, methodology used for the Vekol Wash Tributary hydrology follows the requirements of the DDMMC. Any exceptions to the methodology are discussed below. The US Army Corps of Engineers' HEC-1 computer software program was used to perform calculations.

Technical Approaches:

1. *Precipitation – A basin average precipitation value based on NOAA 14 was used in the HEC-1 model. (Note: For localized design purposes, specific rainfall depth should be used for each basin)*

2. *S-graphs will be used and converted into unit hydrographs to perform the hydrologic routing. The Clark Unit Hydrograph will not be used as it has an upper watershed limit of 10 square miles.*

3. *Rainfall losses for each subbasin will be calculated using Green and Ampt. Channel transmission losses will be assumed to be zero in man-made and lined channels. Normal depth routing will be used in most routing reaches except for small man-made channels for little potential for flow attenuation where the kinematic wave method will be used.*

4. *Stock ponds and agricultural water quality storage basins will be assumed to be full in all storm events.*

5. *Canals, railroad embankments, and roadway embankments will be assumed to remain intact and functional during all storm events unless a reasonable expectation of failure exists. An example of a reasonable expectation of failure would be overtopping of an embankment during a storm event where the overtopping location was not specifically designed to carry such flows. Diversions are added where flow splits are expected to occur.*

6. *Conveyance from detention basin bleed pipes will be ignored for pipe sizes 24" in diameter and smaller. Basins will be assumed to be 80% effective, including underground retention.*

1.2 Model Description

A hydrology model was created for the 100-year frequency (1% chance) storm, for the 24-hour storm event for the existing condition. The Pinal County manual dictates the use of the 24-hour storm, and FEMA dictates the use of the 100-year frequency for flood insurance studies. Flows larger than the 1% chance storm runoff can and do happen and are not analyzed as part of this project. Land use was based on existing conditions.

The HEC-1 model was initially created using the newest version of the Flood Control District of Maricopa County's (FCDMC) Drainage Design Management System for Windows (DDMSW, Version 4.1.9). The software aids in creating HEC-1 files, and performs many calculations for the user, such as creating UI cards, calculating NSTPS (number of calculation steps during routing), and compositing land use parameter values.

1.3 Subbasin Delineation

Subbasin delineation was accomplished using USGS topographic sources, 2008 2-foot contour interval topography within the City of Maricopa limits, the *Pinal County Maricopa Area Drainage Master Plan* (Stantec, 2004), aerial photography, and available reports. In general, the target minimum subbasin size was 1 square mile. However, exceptions exist due to basin characteristics. Subbasin boundaries are shown graphically on **Plates 1 and 2**. **Plate 1** additionally includes the general flow schematic.

The UPRR tracks were chosen as the downstream limit to the study. The tracks are elevated and therefore cause hydraulic differences due to potential ponding behind the tracks. Current FEMA standards require that floodplains are based on the worst-case scenario of the tracks failing or remaining intact during flood events. Although the two worst-case scenarios can not happen simultaneously, flood insurance maps cover both instances to be conservative. The worst-case scenario for flooding upstream is the tracks remaining intact, and the worst-case scenario for flooding downstream is the tracks failing. However, for the purposes of this study, the effects of the tracks are not included so that a 1%-chance flow arriving at the tracks can be determined.

The Vekol Wash Tributary model relative to the UPRR embankment consists of two sub watersheds; one watershed is associated with Concentration Point 97 and one watershed associated with Concentration Point 99 (approximately 119 square miles and 77 square miles, respectively). They are not mutually exclusive due to flow splits, which are discussed in detail below.

1.4 Land Use

A majority of the watershed is either used for agricultural purposes or is vacant, undeveloped desert land. The Table Top Wilderness area is located in the upper portion of the watershed. Additionally, a large part of the watershed is within the Ak-Chin Indian Reservation. The reservation is using most of the land for agricultural or residential purposes.

An existing conditions land use shapefile was created for this project, shown graphically on **Plate 3**. Existing conditions land use was created by visual inspection of the watershed, and summarized into general land use codes.

The land use codes used for this project generally follow the allowable land use codes found in the DDMSW program. These codes and specific runoff parameter values are summarized in Table 1.4.1, below.

Table 1.4.1 – Land Use Codes

Land Use	LUCODE	Land Use (Level 4 - Detailed)	Description	Kn	RTIMP
Single Family Low Density - Less than 1 du/ac	**110**	Rural Residential	<= 1/5 du* per acre (SF)	0.035	5
Single Family Medium Density - 1 to 4 du/ac	**130**	Large Lot Residential (SF)	1 du per acre to 2 du per acre (SF)	0.035	15
Single Family High Density - Greater than 4 du/ac - Includes Mobile Homes	**160**	Very Small Lot Residential (SF)	>6 du per acre (SF)	0.030	35
Multi Family	**170**	Medium Density Residential (MF)	5-10 du per acre (MF)	0.022	45
Retail Low - Amusement/Movie Theatre/Specialty Retail/Neighborhood Retail	**200**	General Retail	Commercial where no detail available	0.025	80
Tourist Accommodations - Motel/Hotel/Resort	**510**	Tourist and Visitor Accommodations	Hotels, motels and resorts	0.030	40
Transportation	**610**	Transportation	Freeways/Expressways/ Highways/ Major Roads/ Arterials/ ROWs where no detail available	0.018	95
Passive/Restricted Open Space	**730**	Passive Open Space	Includes mountain preserves and washes	0.050	0
Agriculture	**750**	Agriculture	General Agriculture	0.100	0**

*du=dwelling unit; **Soils information may contribute additional RTIMP values. This is for land use parameters only.

"Kn", an estimated mean of all Manning's roughness coefficient values for the drainage pathways for the area, is calculated in this model based on the land use percentages for each subbasin. This calculation weights the percentage of Kn for each land use type by area within the subbasin.

1.5 Soils

Soil characteristics were obtained from the USDA NRCS Web Soil Survey AZ659, for Pinal County, Arizona, Western Part, Version 7 dated September 4, 2008. A very small section in the southeast area of the watershed study was not covered by the existing maps. The soil data for this section was interpolated based on aerial and adjacent soil types mapped. A summary of the soil classifications for each subbasin is shown on **Plate 4**.

Agricultural land has different runoff characteristics than all other land uses. To model runoff from agricultural land, the following approach was used as summarized below in Table 1.5.1. This approach was developed through numerous previous studies and projects within Maricopa County, Arizona (see references) and is applicable to agricultural sites in areas of relatively low slopes in Pinal County and the Vekol Tributary watershed.

Table 1.5.1 – Agricultural Modeling Parameter Approach

Parameter	Methodology Value
Flow Routing	Flow routed in ditches or conveyance structures until capacity is accounted for, then additional needed capacity from the adjacent fields.
Lag Time Equation (Kn)	0.06 < Kn < 0.15
Initial Abstraction (IA)	0.5 inch
Volumetric moisture deficit (DTHETA)	Soils should be considered to be in a normal condition (not saturated)
Wetting front capillary suction (PSIF)	Varies, Use current FCDMC recommended values
Hydraulic conductivity (XKSAT)	Varies, Use current FCDMC recommended values
Percent impervious (RTIMP)	Based on land use, ag land typically 0 unless impervious improvements exist

The Green and Ampt methodology as it applies to soil characteristics is described as follows (taken from Section 4.4.1 of the DDMMC, November 2003 (Draft) edition):

> “Use of the Green and Ampt equation as coded in HEC-1 involves the simulation of rainfall loss as a two phase process…The first phase is the simulation of the surface retention loss…called the initial loss (IA) in HEC-1. During this first phase, all rainfall is lost (zero rainfall excess generated) during the period from the start of rainfall up to the time that the accumulated rainfall equals the value of IA. It is assumed, for modeling purposes, that no infiltration of rainfall occurs during the first phase. Initial loss (IA) is primarily a function of land use and surface cover...The second phase of the rainfall loss process is the infiltration of rainfall into the soil matrix. For modeling purposes, the infiltration begins immediately after the surface retention loss (IA) is completely satisfied…The three Green and Ampt equation infiltration parameters as coded in HEC-1 are:

- hydraulic conductivity at natural saturation (XKSAT) equal to K_s…;
- wetting front capillary suction (PSIF)…; and
- volumetric soil moisture deficit at the start of rainfall (DTHETA)….

The three infiltration parameters are functions of soil characteristics, ground surface characteristics, and land management practices. The soil characteristics of interest are particle size distribution (soil texture), organic matter, and bulk density. The primary soil surface characteristics are vegetation canopy cover, ground cover, and soil crusting. The land management practices are identified as various tillages as they result in changes in soil porosity."

1.6 Routing

The routing of flow through the basins was estimated by preparing an 8 point cross section along the routing reach. Routing reaches, the path flow will follow during a runoff event, were determined by using all available sources (as described above) and estimating the probable flow path from one concentration point to another. In many cases, specific data was not available and estimations were necessary.

The *Pinal County Maricopa Area Drainage Master Plan* (Stantec, 2004) contained field surveys of many of the washes in the watershed. The HEC-1 model contains the applicable reference sections from the study in the comment cards of the routing reaches.

1.7 Unit Hydrographs and Rainfall Excesses

Rainfall excesses are transformed into runoff in the form of a unit graph with the UI card in HEC-1 (the HEC-1 software entry for a unit hydrograph). The UI card is generated within the DDMSW software which transforms rainfall excesses into runoff in a pattern dependent on the soil characteristics. However, due to a limitation in the software, the hydrograph is occasionally truncated prematurely. This occurs where the peak is "spread out", particularly in long, narrow basin shapes.

This truncation does not affect the peak flow values. All unit graphs were checked to ensure the peak had sufficiently passed prior to truncation. To ensure that excess volume was not created, the hydrograph was forced to zero. The reason for this is that HEC-1 may carry the last input number out to completion of the time step (leaving a "tail" on the hydrograph). Therefore, in order not to produce excess volume, the zero was added. This may produce slightly less total volume estimates should the model be used in the future for storage calculations, but it is not anticipated to be significant as the majority of the hydrograph is included prior to truncation.

1.8 Storage

Several regional retention basins exist in the watershed. As-built information for the regional basins was previously determined in the *Pinal County Maricopa Area Drainage Master Plan* (Stantec, 2004). Local retention/detention basin storage volumes were determined from drainage reports for the subdivision development. The reports are listed in Section 3.0, References.

Additional storage occurs by ponding behind elevated features (canals, railroad tracks and roadways). In the Vekol Tributary watershed, storage of significance in hydrologic modeling was seen to occur behind the CAP canal that crosses the watershed. Although this structure has numerous siphons and overchutes, instances of localized ponding were seen, as evidenced in the vegetation differences in the ponded areas. An estimate of the ponding was made based on topographic mapping and the height of the canal (as taken from USGS topographical source), and included in the model as a volume diversion. Storage data is summarized below in Table 1.8.1.

Table 1.8.1 – Storage

Storage ID	Supporting Documentation
SR64A, SR64B, SR64C	CVL Detention Basin #5, #6, #7 respectively, refer to CVL's Santa Rosa LOMR HEC-1 Model.
D18RE, D59RE, D57RE, D55RE	Ponding area along CAP Canal, see Figure 1.8.1 and Figure 1.8.2 (Attachment A)
D26RE	Volume calculated from CVL stage-storage routes D1, D2, D3, D4; refer to CVL's Santa Rosa LOMR HEC-1 Model.
D72RE	White Rd Basin Retention calculated assuming 5-ft depth, see Figure 1.8.3 (Attachment A)
D97RE	Alterra and Maricopa Meadows Reports and calculated per aerial where no report coverage. Volume calculated assuming 3-ft depth ponding, documentation provided in Attachment C.

Additional localized storage may be occurring in the watershed due to smaller-scale agricultural berms, local row crops, and irrigation/water quality structures. This potential storage is ignored for this model for the following reasons: the items causing storage were not constructed for flood control purposes and may fail during flooding, crops are frequently rotated, agricultural land is often fallow during part of the year or from year to year, and row crops directions may shift. In general, local areas of storage due to agricultural grading are not reliable from year to year for flood protection purposes. As previously mentioned, stock ponds and agricultural ponds are assumed to be full and disregarded in terms of storage.

1.9 Diversions and Flow Splits

Flow splits were estimated at locations where the capacity of a conveyance structure was shown to be exceeded. An initial run of the model was made to determine flow amounts arriving at conveyance structures. Diversions were added in the model where the capacity of the structure was exceeded and flow would be expected to be transferred between subbasins.

An important diversion that governs the arrival of the flow at the City of Maricopa limits exists at the intersection of Smith Wash (approximately the Steen Road alignment) and SR347 (John Wayne Parkway). This location is called CP92 in the HEC-1 model. At this point, the flow that will cross the Parkway to the west is limited by the capacity of the culverts, which is approximately 2,000 cfs. The remainder of the flow will overtop the channel and flow to the north. The reason for the flow to the north instead of the roadway overtopping is that the grades to the north are approximately 10 feet lower than the top of roadway grade, according to the 2008 two-foot contour interval topographic mapping.

Flow Diversion location CP92

The road generally remains higher than adjacent grades, although at varying height differences, for the remainder of the watershed. However, additional flow splits (or diversions) exist along SR347. During detailed hydraulic analysis performed as part of the downtown CLOMR study, the next Phase of the City of Maricopa Master Drainage Study and Plan, additional investigation was performed on the flow divisions along John Wayne Parkway (discussed below). This helped further refine the flow splits along SR347, which were put in the hydrology model as two additional diversions, D96NW and D96ANW. Flow splits are summarized in **Table 1.9.1**, below.

Table 1.9.1 – Diversions

Diversion ID	Supporting Documentation
D09NW	Divert estimate from aerial and USGS mapping, see Figure 1.9.1 (Attachment A)
D68NW	Divert estimate based from Stantec channel section (Stantec, 2004). 2731 cfs is confined in channel. Remainder of flow goes NW.
D92NW	Divert estimate based on capacity of 6-10x6 RCBC (Stantec, 2004). 2000 cfs capacity continues west, remainder goes North.
D96NW	Divert estimate based on EX Conditions HECRAS flow weir over John Wayne Parkway (Table 1.9.2, HEC-RAS Lateral Structure Output, River Sections 699 and 599); capacity continues west, remainder goes North
D96ANW	Divert estimate based 3-8'x5' RCBC under John Wayne Parkway (CVL, 2003); capacity continues west, remainder goes North

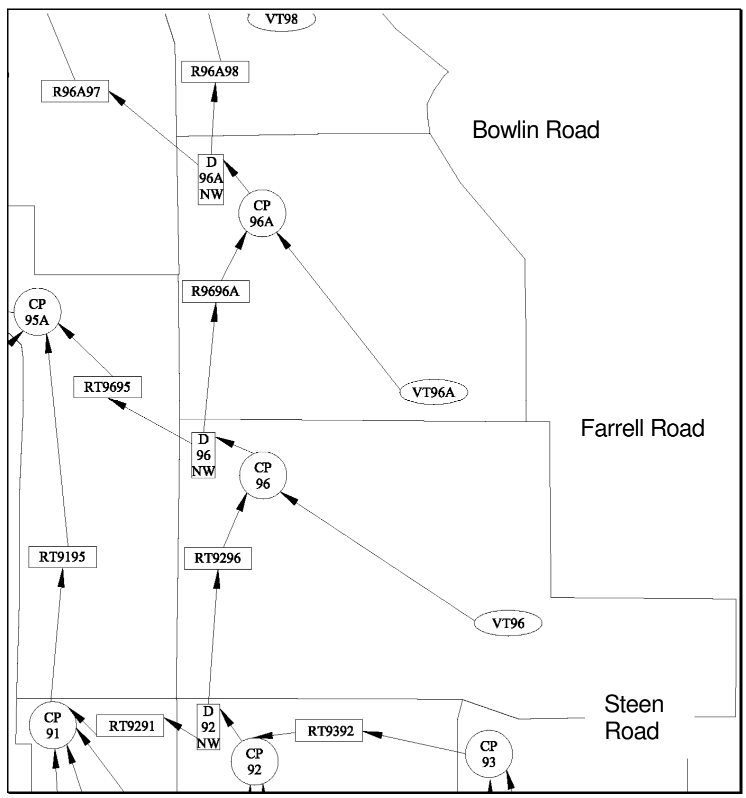
1.9.1 Hydraulic Analysis – SR347 (John Wayne Parkway)

As previously mentioned, additional investigation was performed on the flow divisions along SR347. This detailed hydraulic analysis, utilizing U.S. Army Corps of Engineers' HEC-RAS software, Version 3.1.3, was conducted to determine the direction and containment of flow as it enters the City of Maricopa limits. Modeling SR347 as a series of lateral weirs, it was determined that flow diverts west over the road at two additional locations.   This warranted additional split flow diversions shown in Table 1.9.1 to be added to the hydrology model to better detail the flows as they enter the City.

Table 1.9.2 – Lateral Structure HEC-RAS Output

HEC-RAS Plan: p01   River: Vekol Wash Tribu   Reach: 1   Profile: PF 1

Reach	River Sta	Q US	Q Leaving Total	Q DS	Q Weir	Q Gates	Wr Top Wdth	Weir Max Depth	Weir Avg Depth	Min El Weir Flow	E.G. US.	W.S. US.	E.G. DS	W.S. DS
		(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
1	799	10000.00	0.00	10000.00						1194.00	1196.74	1196.69	1193.45	1193.12
1	699	10000.00	525.53	9452.00	525.53		1204.44	0.56	0.27	1190.03	1193.45	1193.12	1190.27	1190.18
1	599	9474.79	22.67	9452.00	22.67		223.03	0.19	0.10	1188.53	1190.27	1190.18	1188.07	1187.56
1	499	9452.00	0.00	8522.58						1183.27	1188.07	1187.56	1182.80	1182.70
1	399	9452.00	941.59	8522.58						1182.61	1182.80	1182.70	1180.47	1180.09
1	299	8522.58	0.00	8522.58						1182.46	1180.47	1180.09	1178.98	1178.52
1	249	8522.58	0.00	8522.58						1179.02	1178.98	1178.52	1176.21	1176.11
1	199	8522.58	0.00	8522.58						1175.75	1176.21	1176.11	1175.10	1174.84



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HEC-1 Schematic: Flow Split D96NW and D96ANW across SR 347

1.10 Areal Reduction

Areal reduction is a major component in large watersheds such as this study area that have flow diversions. The depth of rainfall that is expected to occur at a point in a watershed for a specific frequency and duration needs to be averaged to reflect the areal extents of the rainfall over the basin. The “loss” of tributary area can occur in modeling because the flow diverted from the main flow stem does not “carry” the tributary area accumulated upstream of the diversion.

Hence, at the location where the diverted flow is retrieved, the tributary area accumulated upstream of the hydrograph combine will not account for this upstream area associated with the retrieved flow. In order to correct for this potential error, a cumulative upstream storm area was determined and hard-coded into the model.

1.11 Schematic

In order to facilitate the review and use of the model by others in the future, a HEC-1 schematic was generated. The schematic shows all operations of the model (basin, routing, storage, etc.) and how they relate to each other. The schematic is shown graphically on **Plate 1**.

1.12 Percent Impervious (RTIMP)

The percent impervious (RTIMP) for each subbasin is calculated based on percentages of both soil and land use contributions to imperviousness in each subbasin. These calculations are done automatically through the DDMSW software, and are based on the RTIMP values assigned to the land use type and adjusted per the soil types in each subbasin. Therefore, a composite RTIMP is created from the contributions of both soil and land use to the value.

1.13 Precipitation

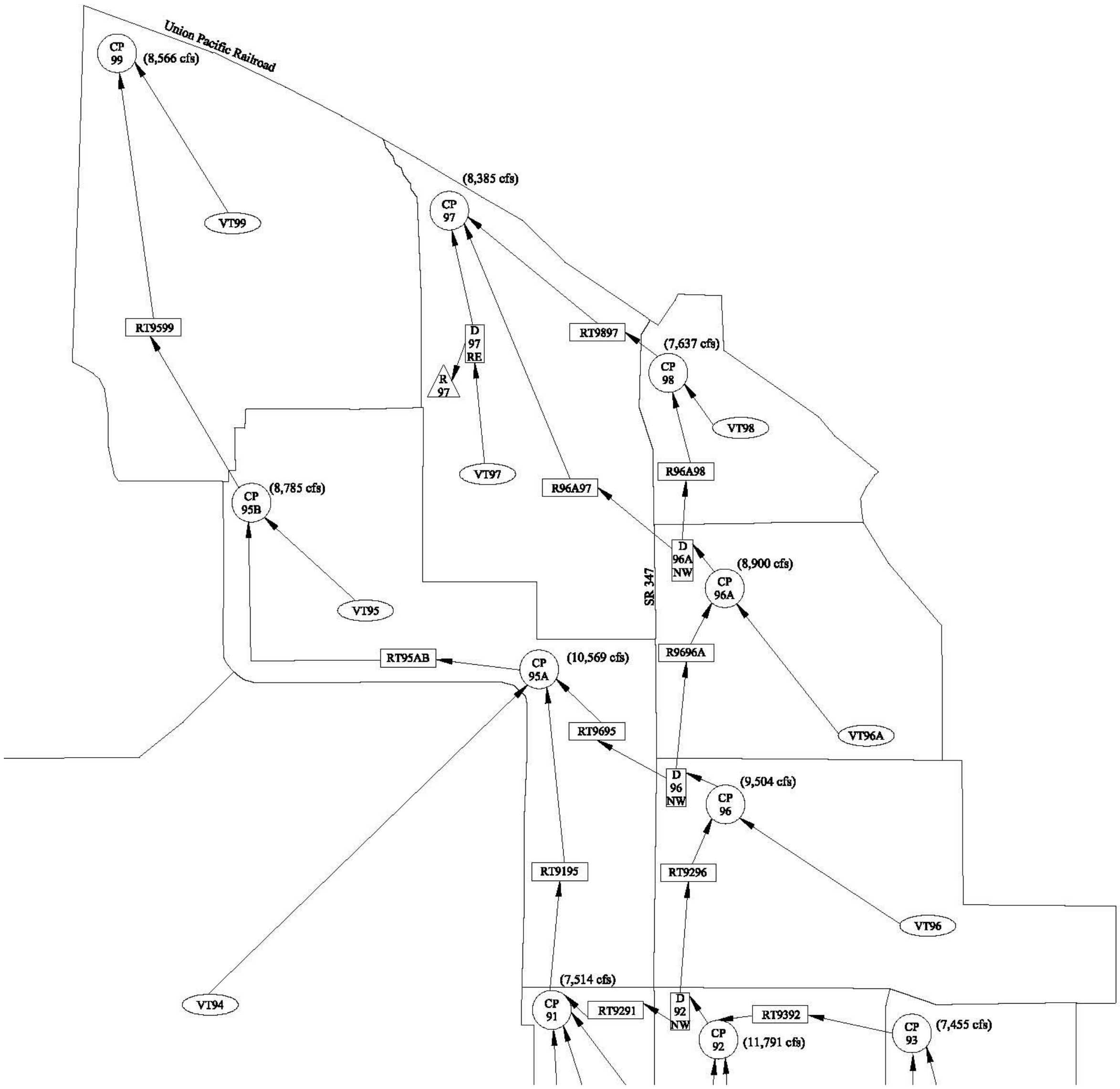
As previously discussed, NOAA Atlas 14 precipitation estimates were used in this model. DDMSW includes a NOAA Atlas 14 Design Storm Map Index that allows the user to define cells of the project limits based on Township, Section and Range, included in Attachment C. Based on the cells the user enters, DDMSW runs the PREFRE model to populate the average rainfall data for the project. This results in a more accurate basin-average precipitation value. The 100-year, 24-hour NOAA Atlas 14 basin-average precipitation value for this model is 3.81 inches.

2.0 RESULTS

The HEC-1 model produced flow estimates for the 100-year, 24-hour event for the Vekol Wash Tributary. The flow arrival at the downstream limits of the watershed, the UPRR tracks, is subject to upstream flow diversions due to natural and man-made features. Electronic files associated with the results of this project are included in Attachment E. Files include all HEC-1 input and output files, and supporting CAD and GIS files.

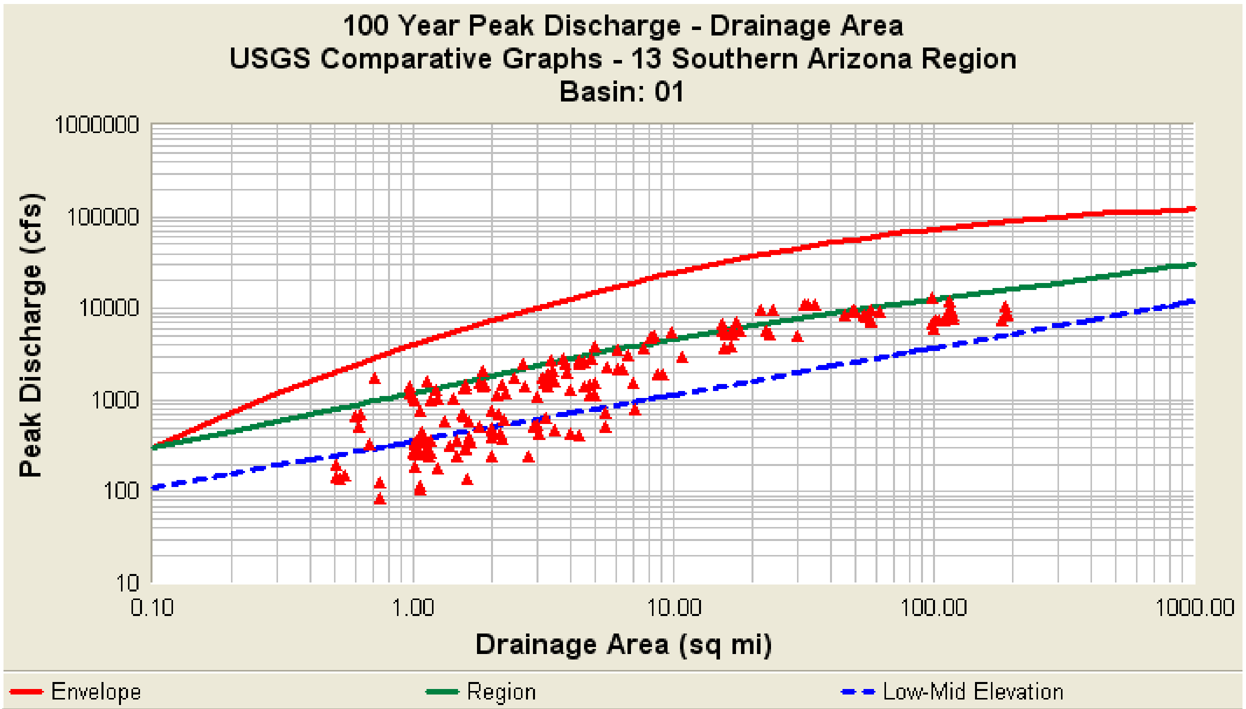
The two key downstream concentration points, CP99 at the western-most downstream location and CP97 near the Green Road alignment, have flows of 8,566 cfs and 8,385 cfs respectively. The existing UPRR cross conveyance structures under the tracks are not capable of handing flows of this magnitude, and therefore some ponding or potential overtopping of the tracks is possible.

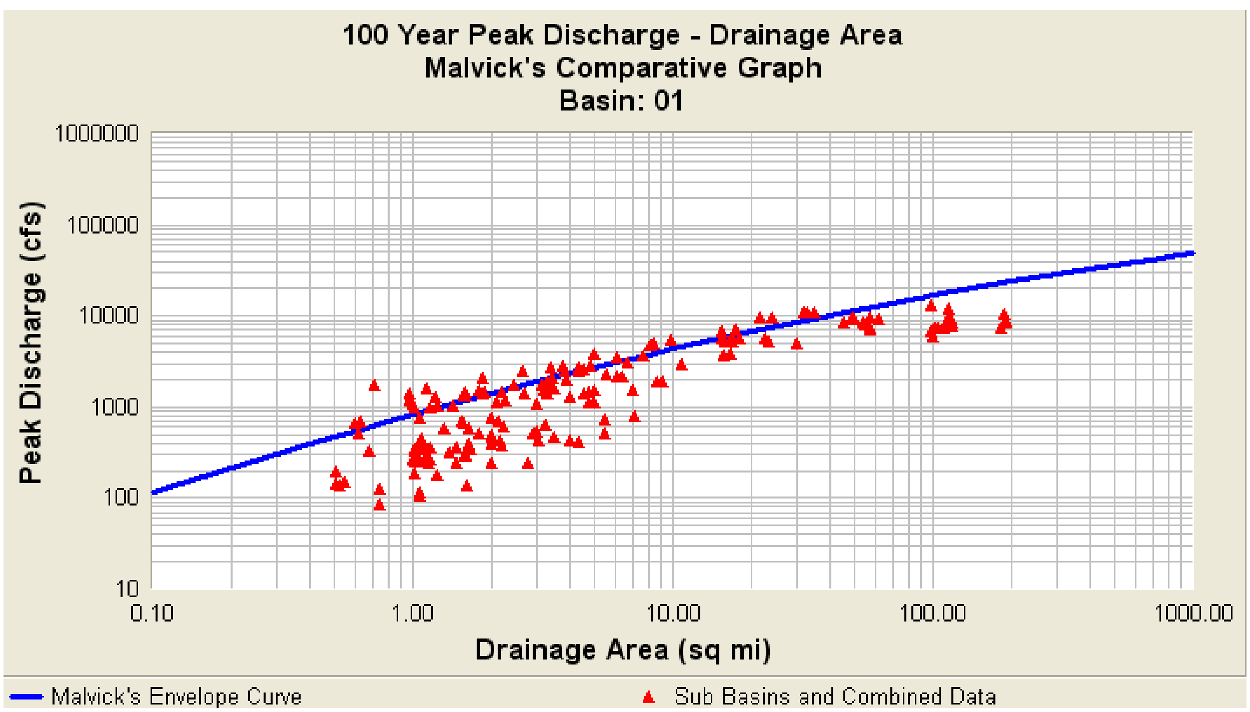
Important diversions exist along John Wayne Parkway (SR347) at locations between the Smith-Maricopa Wash intersection (approximate Steen Road alignment) and the limits of the study at the UPRR tracks. At these diversions, flow is expected to overtop SR347 and continue to the northwest towards the Vekol Wash Tribtary and Vekol Wash crossings of the UPRR tracks. Therefore, the diverted flow would not contribute as a flooding source for the downtown area.

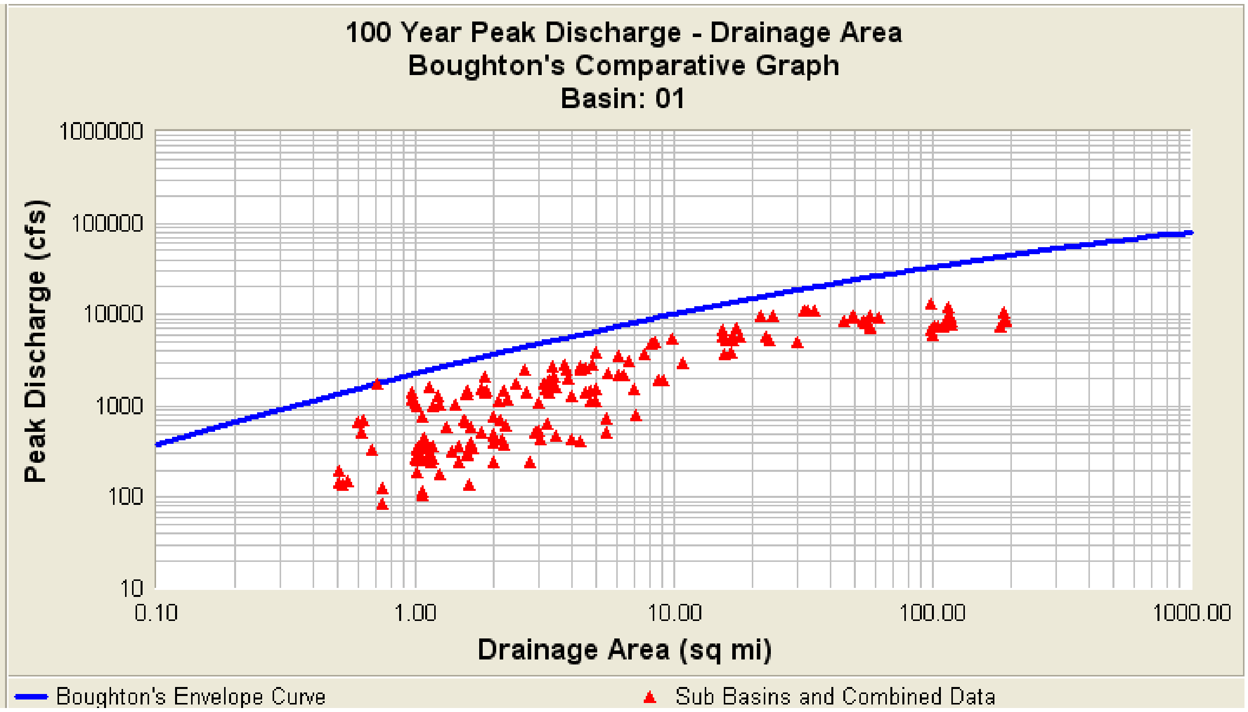


100-year, 24-hour HEC-1 modeling results, Vekol Wash Tributary, City of Maricopa, Arizona

Graphs were created to compare the results against indirect methods, such as regional regression curves. Based solely on area, the regression equation result using the Region 13 equation for CP97 at 120 square miles is approximately 14,000 cfs. Therefore, the HEC-1 result of 8,385 cfs appears reasonable, slightly lower due to the upstream diversions along SR347.


100 Year Peak Discharge - Drainage Area
USGS Comparative Graphs - 13 Southern Arizona Region
Basin: 01
Peak Discharge (cfs)
1000000
100000
10000
1000
100
10
0.10
1.00
10.00
100.00
1000.00
Drainage Area (sq mi)
Envelope
Region
Low-Mid Elevation


100 Year Peak Discharge - Drainage Area
Malvick's Comparative Graph
Basin: 01
Peak Discharge (cfs)
1000000
100000
10000
1000
100
10
0.10
1.00
10.00
100.00
1000.00
Drainage Area (sq mi)
Malvick's Envelope Curve
Sub Basins and Combined Data



The graphs indicate general agreement between the detailed model created for this study and the approximate methods shown above. These curves are developed by a best-fit method from undeveloped and unregulated watersheds, so differences would be expected where there is retention, diversion, steep slopes, high impervious, low impervious, ponding, etc. The USGS data was derived from the information obtained in “Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States”, USGS Water Supply Paper 2433. The Malvick data was derived from “A Magnitude-Frequency-Area relation for Floods in Arizona”, Allan Malvick, January 1980. The Boughton data was derived from “Highway Drainage Design Manual Hydrology”, Report Number FHWA-AZ93-281, March 1993. The Malvick study, being the oldest study, is considered outdated although still indicates general agreement.

3.0 REFERENCES

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U.S. Department of Homeland Security, Federal Emergency Management Agency, *Flood Insurance Study Pinal County, Arizona and Unincorporated Areas*, Number 04021CV001A, December 4, 2007.

U.S. Geological Survey, 7.5' Topographical Maps, various quadrangles.